DESIGN AND ANALYSIS OF A REAR WHEEL COVER FOR A CAR USING COMPUTATIONAL FLUID DYNAMICS (CFD)

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A report submitted in partial fulfillment of the requirements for the award of the degree of Bachelor of Mechanical Engineering with Automotive Engineering

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NOVEMBER 2009

SUPERVISOR DECLARATION

"I hereby declare that I have read this thesis and in my opinion this thesis is sufficient in terms of scope and quality for the award the degree of Bachelor of Mechanical Engineering"

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Date : November 2009

STUDENT DECLARATION

I declare that this thesis entitled "Design and analysis of a rear wheel cover for a car using computational Fluid Dynamics (CFD)" is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature : …………………………………………….

Name : KOGILAN A/L GOVINDASAMY

Date : NOVEMBER 2009

This work is dedicated to my beloved ones,

My Father Mr. Govindasamy Manu

My Mother Mrs. Puspa Sinasamy

My Brother Mr. Sri Tharan Govindasamy

My Sisters Ms. Pannir Selvi Govindasamy and Ms. Sinth Mani Govindasamy

And

My Niece Ms. Sathiavathy Mahendran

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ABSTRACT

The performance and handling of automobile are significantly affected by its aerodynamic properties. One of the main causes of aerodynamic is about drag force and lifting force. This will influence all the aspect of the vehicles such as overall performance, fuel consumption, safety and stability. However, the unavoidable need for wheels caused and even recently causes significant problems for aerodynamicists to deal with the flow. The addition of wheelhouses and rotating wheels to an aerodynamically optimized car body, leads to decrease in drag and lift coefficients by 30% and 40%, respectively. In an aerodynamic field, the main important thing to get the stability, performance and good fuel consumption is to design a vehicle with low C_D. The reduction of lift and flow separation is the key results that will be a point of discussion. Rear wheel cover will reduce the flow separation at the wheel houses that causing the turbulent airflow. The wake region also will be reduced and this will make the drag force that produce at the wheel houses will reduced. By the lower drag force will contribute to the lower fuel consumption. The task was done by doing a Computational Fluid Dynamic (CFD) analysis for expected vehicle speed of 40-140 km/h. A drag force was found based on inputs from CFD analysis. This force was calculated to produce the drag coefficient of the model as a whole. The approach needed to justify the amount of drag that can be reduced by addition of a rear wheel cover as compared to the model without the rear wheel cover. This project is to get an overall comparison of the velocity and pressure distribution before and after the rear wheel cover is added. The drag coefficient of the vehicle was decreases from 0.3882 to 0.3773 when adding the rear wheel cover.

ABSTRAK

Ciri-ciri aerodinamik adalah sangat mempengaruhi akan prestasi dan kawalan sesebuah kenderaan. Salah satu kesan penyebab akan aerodinamik adalah geseran atau daya seretan dan daya tujahan. Ini akan mempengaruhi kesemua prestasi, penggunaan minyak, keselamatan, dan kestabilan sesebuah kenderaan. Walaubagaimanapun, penggunaan roda tidak dapat dilelakkan dan ini telah menyebabkan masalah untuk aerodynamisis untuk menangani dengan aliran udara. Hasil tambahan penutup tayar dan putaran roda kepada badan kereta yang dioptimumkan secara aerodinamik menyebabkan pekali seret menurun sebanyak 30% dan pekali daya angkat sebanyak 40%. Di dalam aspek aerodinamik, kestabilan, prestasi dan penggunaan minyak amat penting untuk menghasilkan kenderaan yang rendah C_D. Pengurangan tujahan dan peyebaran udara adalah kunci utama di dalam perbincanganPenutup tayar belakang juga akan menghasilkan peyebaran pengaliran udara yang kurang di belakang kerana ini akan menghasilkan pegaliran udara yang bergelora. Kawasan olak di belakang juga akan berkurangan dan ini akan menjadikan daya geseran yang terhasil di bahagian belakang tayar kenderaan berkurangan. Dengan nilai daya geseran yang rendah, ia akan membantu dalam penggunaan minyak yang rendah. Tugasan ini dimulakan dengan menggunakan kelajuan yang telah ditetapkan pada 40 km/j hingga 140 km/j dengan menggunakan analisis Computational Fluid Dynamic (CFD). Daya geseran akan didapati apabila menggunakan perisian maklumat daripada CFD analisis. Nilai daya ini akan digunakan untuk mengira pekali geseran keseluruhan model kereta tersebut. Nilai pengurangan geseran yang terhasil daripada penutup tayar belakang diperlukan untuk menbenarkan pembezaan di antara model tanpa penutup tayar di belakang. Projek ini akan mendapatkan perbezaan berdasarkan pegaliran angin dan tekanan sebelum dan selepas penutup tayar belakang dipasangkan. Pekali seret bagi kenderaan menurun dari 0.3882 ke 0.3773 apabila penutup tayar belalang dipasangkan.

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LIST OF SYMBOLS

F_L	Lift force
ρ	Density
V	Velocity
V_o	Wind velocity (reversed direction)
A	Area
P	Pressure
$\mathrm{P}_{\mathrm{atm}}$	Atmosphere pressure
C_D	Drag coefficient
F_D	Drag force
$^{\circ}$	Degree of angle
ℓ	Length
$P_{\check{r}}$	Prevailing pressure
T	Temperature
μ	Viscosity
U	Dynamic viscosity
Re	Reynolds Number
%	Percentage
θ	Angle
P	Aero power

LIST OF ABBREVIATIONS

HEV	Hybrid Electrical Vehicle
CFD	Computational Fluid Dynamic
CAD	Computational Aided Design
km/h	kilometer per hour
m/s	mile per second
mph	mile per hour
mm	millimeter
kW	kilowatt
N	newton

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CHAPTER 1

INTRODUCTION

1.1 Background

A car driven in a road is affected by aerodynamic forces created. In all these categories, the aerodynamics of such cars is of vital importance. They affect the cars stability and handling. They influence both performance and safety. Aerodynamics is the branch of dynamics that deals with the motion of air and other gaseous fluids and with the forces acting on bodies in motion relative to such fluids. For some classes of racing vehicles, it may also be important to produce desirable downwards aerodynamic forces to improve traction and thus cornering abilities. Most everyday things are either caused by aerodynamic effects or in general obey the aerodynamic laws. For aerodynamic bodies is simplifies procedure may then be devised for the evaluation of the aerodynamic loads.

1.2 Problem Statement

Most of moving vehicle produces drag because of the turbulent air of airflow separation. These will produce the drag force and the reduction of drag is essential for improving performance and fuel consumption. In the last century, particularly in its last 30 years the possible lowest drag have been approached. In every vehicle movement, the air flow will go through to the wheel houses of the vehicle. This air flow will make the drag and friction. To avoid the air flow through the wheel houses, rear wheel cover is suggested. This device is hoped to reduce the drag force and the drag coefficient when the vehicle moving in high velocity. By this the objectives of the project will achieved.

1.3 Objectives

The objectives of the project are as follows:

i. To analyze the effect of rear wheel cover on a vehicle in term of drag coefficient.
ii. To reduce the drag coefficient of the car by modifying the wheel cover area.

1.4 Scopes of Study

The scopes of the project are as follows:

i. Study on aerodynamics drag reduction by rear wheel cover.
ii. Redevelop the existing model of rear wheel cover with Solid Works.
iii. Simulate the model by using Computational Fluid Dynamic (CFD).
iv. To compare the drag for both with and without rear wheel cover.

CHAPTER 2

LITERATURE REVIEW

2.1 Automotive Aerodynamics

Aerodynamics at cars became more and more important with the increase of their velocity. In the beginning of the 20th century, the shape of vehicles was adopted from the field of aviation and ships. Cars had an aerodynamic shape but their velocity was very low, mainly due to the quality of the roads [14]. Aerodynamics is the branch of dynamics that deals with the motion of air and other gaseous fluids and with the forces acting on bodies in motion relative to such fluids. Automotive aerodynamics is the study of the aerodynamics of road vehicles. The main concerns of automotive aerodynamics are reducing drag, reducing wind noise, minimizing noise emission and preventing undesired lift forces at high speeds. For some classes of racing vehicles, it may also be important to produce desirable downwards aerodynamic forces to improve traction and thus cornering abilities [1]. An aerodynamic automobile will integrate the wheel and lights in its shape to have a small surface. It will be streamlined, for example it does not have sharp edges crossing the wind stream above the windshield and will feature a sort of tail called a fastback or Kammback or lift back. It will have a flat and smooth floor to support the venturi or diffuser effect and produce desirable downwards aerodynamic forces. The air that rams into the engine bay, is used for cooling, combustion, and for passengers, then reaccelerated by a nozzle and then ejected under the floor. Most everyday things are either caused by aerodynamic effects or in general obey the aerodynamic laws. For aerodynamic bodies is simplifies procedure may then be devised for the evaluation of the aerodynamic loads.

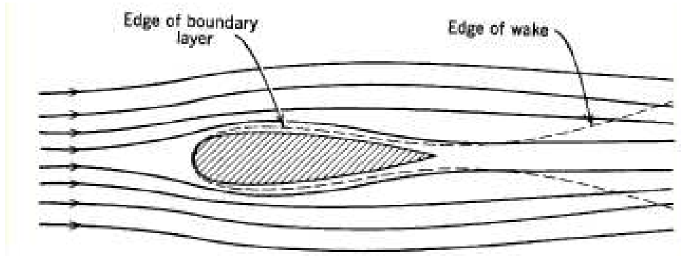

Figure 2.1: Aerodynamic of bluff bodies [1]

A car driven in a road is affected by aerodynamic forces created. The aerodynamics of such cars is of vital importance. They affect the cars stability and handling. They influence both performance and safety.

2.2 Aerodynamic Force

2.2.1 Forces

A body in motion is affected by aerodynamic forces. The aerodynamic force acts externally on the body of a vehicle. The aerodynamic force is the net result of all the changing distributed pressures which airstreams exert on the car surface [3]. Aerodynamic forces interact with the vehicle causing drag, lift, down, lateral forces, moment in roll, pitch and yaw, and noise. These impact fuel economy, and handling. The aerodynamic forces produced on a vehicle arise from two sources that are form (or pressure) drag and viscous friction. Forces and moment are normally defined as they act on the vehicle. Thus a positive force in the longitudinal (x-axis) direction on the vehicle is forward. The force corresponding to the load on a tire acts in the upward direction and is therefore negative in magnitude (in the negative z-direction). The forces also corresponding to the shape on the vehicle part in aerodynamic shape. Figure 2.2 below shown of the vehicle most significant forces [2].

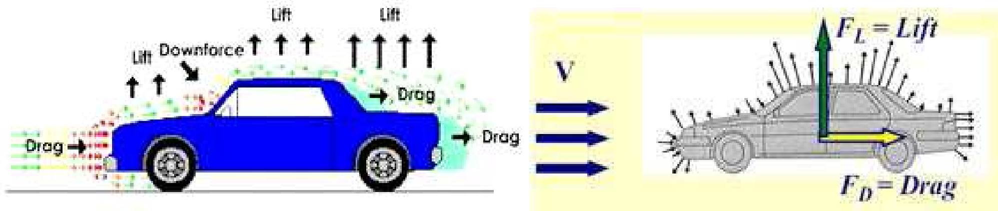

Figure 2.2: Arbitrary forces and origin of the forces acting on the vehicle [2] [3]

Table 2.1: Forces acting on moving vehicle

Direction	Force	Moment
Longitudinal (*x*-axis, +*ve* rearward)	Drag	Rolling moment
Lateral (*y*-axis, +*ve* to the right)	Side force	Pitching moment
Vertical (*z*-axis, +*ve* upward)	Lift	Yawing moment

The focus in cars is on the aerodynamic forces of down force and drag. The relationship between drag and down force is especially important. Aerodynamic improvements in wings are directed at generating down force on the car with a minimum of drag. Down force is necessary for maintaining speed through the corners [3].

2.2.2 Aerodynamic Lift

The other component, directed vertically, is called the aerodynamic lift. It reduces the frictional forces between the tires and the road thus changing dramatically the handling characteristics of the vehicle. In addition to geometry, lift FL is a function of density ρ and velocity V. Lift is the net force (due to pressure and viscous forces) perpendicular to flow direction. The aerodynamic drag coefficient equation is [2.1].

$$C_F = \frac{F_L}{\frac{1}{2}\rho V^2 A} \tag{2.1}$$

F_L = lift force [N]

ρ = density of the air [kg/m3]

A = area of the body [m2]

V = velocity of the body [m/s]

Aerodynamic lift and its proper front-and-rear-axle distribution is one of the key aspects in terms of on-road stability [4]. As long as driving speed is low, below say 100 km/h, lift and pitching moment have only a small effect on the directional stability of a car, even in crosswind. However, at higher speeds this is no longer true, and so recent developments are directed at controlling them.

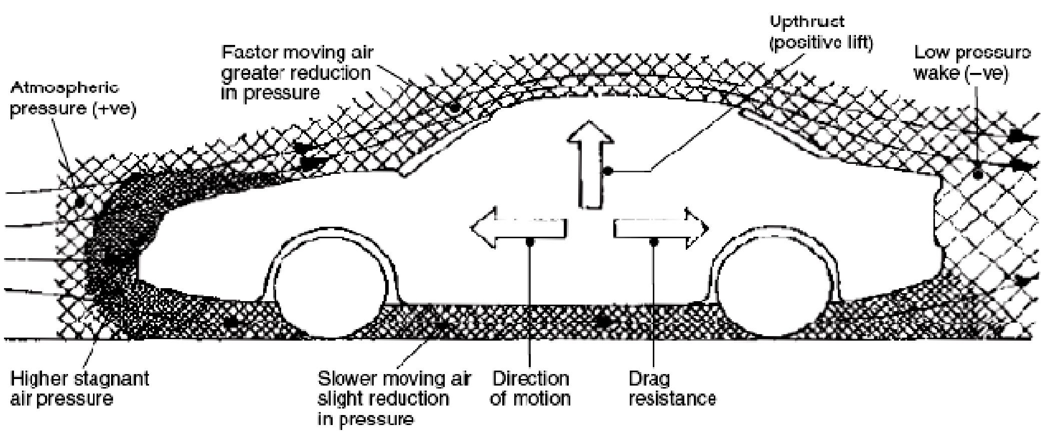

Figure 2.3: Aerodynamic Lift

2.3 Aerodynamic Pressure

The gross flow over the body of a vehicle is governed by the relationship between velocity and pressure expressed in Bernoulli's Equation. Bernoulli's Equation assumes incompressible flow which is reasonable for automotive aerodynamics [2].